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The Application of Geographical Information Systems and the Analytic Hierarchy Process in Selecting Sustainable Areas for Urban Green Spaces: A Case Study in Hue City, Vietnam

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Abstract: In recent years, there has been growing awareness about the roles and benefits of urban green spaces (UGSs), particularly in the context of mitigating the negative effects of climate change, which have become increasingly serious. In Vietnam, the government has allocated considerable resources to the development of UGSs in many cities. However, regarding implementation, UGS development in Vietnam faces many challenges; many cities find it difficult to meet the set criterion regarding the number of green spaces per capita. This research was conducted in Hue City, which is known as one of the greenest cities in Vietnam. The results show that there are twenty-one UGSs in Hue City (with a total area of 88.67 ha). These are located primarily along the Huong River and around the Hue Imperial Citadel. However, under government stipulations, the current number of UGSs is not considered sufficient in proportion to the local population, and will not accommodate the future growth of the population. We applied the analytic hierarchy process (AHP) along with the participation of local residents, using six criteria to map potential areas for future UGS planning. In this, the distance from existing residential areas to potential UGS locations is the most important criterion. The suitability map identified 684 hectares of Hue City as highly suitable for UGSs. This research also proposes a scenario for UGS planning in Hue based on retaining the existing green spaces combined with creating another 35 green spaces, comprising a total area of 167 hectares. This is to meet the needs of local residents by 2030.

Keywords: analytic hierarchy process; land evaluation; Hue City; urban green space

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1. Introduction

Providing a clear (and widely accepted) definition of urban green space (UGS) has always been a challenge for researchers [1]. Urban green spaces are seen as any features within urban areas that use natural vegetative landscaping to supply recreational needs and improve the quality of life/well-being of urban residents [2]. According to the World Health Organization, UGSs are essential parts of public open spaces and are crucial in promoting healthy living conditions for all residents in the city [3]. In this sense, UGSs are fundamental elements used to enhance the well-being of urban residents and the quality of their personal and social lives; UGSs significantly contribute to environmental health [4]. UGSs, as commonly defined by researchers, are open spaces—a combination of public and green spaces—areas with natural plant foliage that are situated within urban areas. The main components of UGSs include vegetation, aesthetic landscaping, and the infrastructure required to serve the needs of urban residents [5,6]. UGSs offer suitable areas for psychological relaxation and alleviation of stress (e.g., stress acquired through urban living). UGSs stimulate social cohesion, support, encourage physical activity, and reduce exposure to air pollutants, noise pollution, and excessive heat [7,8]. Recent research conducted at forty-six study sites worldwide found that urban green spaces are essential in creating conditions for sustainable urban living. They provide many benefits to urban living by positively contributing to the physical, psychological, mental, social, and environmental well-being of urban residents [9]. The benefits of UGSs are also important in the context of climate change (especially in recent years). Much of the current research states that UGSs are productive solutions in mitigating the urban heat island effects [10–12]. Moreover, UGSs also reduce urban flood risks, [13]. In Ulsan, a city in South Korea, the flood damage around "non-green" spaces is 21 times higher than in areas with green spaces [14].

According to many reports, urbanization is occurring at a rapid rate in developing countries, with sub-Sahara Africa, Western Asia, and Latin America showing the highest rates of urbanization [15]. However, there few studies focus on land uses—suitable sites and locations that focus on urban green land development in developing countries [16]. In these developing countries, UGSs are often ranked below other more economically-driven priorities [17,18]. The benefits of urbanization pose difficult choices for city planners who are frequently pressured to prioritize building new infrastructure over retaining or enhancing green spaces [19]. Urban residents in developing countries are willing to pay for urban green areas, with an interest in making their cities more beautiful/greener, improving the environment, and leaving a better legacy for future generations. Recently, a study in China found that in the past 30 years, the average rate of urban green space has increased from 18.9% to 30%, and the overall urban ecological environment has substantially improved [20].

Green space planning and management can be very challenging, especially in densely-populated city areas [21]. The idea of planning green spaces in urban areas is very popular, based on the unique characteristics of each urban area. Nearly thirty years ago, in London, a researcher suggested that green roads would help make the city more beautiful [22]. In Nanjing City, China, a system of three-tiered greenspaces was proposed to usher in substantial improvements to the environmental quality of the city and augment its sustainability [23]. The economic status of the city area also plays an important role in determining UGS planning, regarding creating a vibrant biome environment [24]. In addition, the involvement of the community in the UGS planning process is an important factor that contributes to successful UGS model development (this has been proven in Europe) [25]. A successful greening project should be developed based on the multifunctional view, which encompasses aspects of the economy, environment, biology, and recreation [26]. UGSs based on multi-criteria and the geographical information system have been discussed in many studies over the past sixty years [27–29]. This combined model is increasingly applied and is seen as a useful method to ensure sustainable development in the planning of UGSs (because it satisfies the needs of stakeholders) [16,30]. Among them, GIS and the analytic hierarchy process (AHP) are popularly used for many research site scales worldwide [31–33]. The AHP method is one of the most commonly used for multiple-criteria research that combines the quantitative and qualitative databases of complex systems [34]. This method takes into account all of the participants' opinions and ranks them as weighting scores via the pairwise-compare criteria. Therefore, it is suitable for use in decisions involving the social aspects of these considerations. In addition, GIS is very common in UGS planning as it can provide spatial data as well as the correlation of UGSs in relation to other criteria, such as population density and various characteristics of residential areas [35]. The UGS project can be drawn clearly and visualized based on the spatial dataset in combination with user-created scenarios [36].

Vietnam is currently experiencing one of the most intensive urban transitions in the world [37]. The urbanization rate of Vietnam in 2020 was about 40%, equivalent to an overall urban population of over forty-five million people [38]. However, studies on UGSs in Vietnam are still very rare. According to Scopus data, in the past twenty years, only about ten studies on the topic of UGSs have been conducted in Vietnam. The lack of research on UGSs in Vietnam is a significant obstacle to building sustainable urban areas, especially now that Vietnam is moving toward the goal of sustainable urban development for medium-sized cities [39]. In this context, UGS planning is more meaningful in cities that have been recognized as World Heritage Sites, such as Hue City, central Vietnam. This study uses multiple-criteria decision analysis (MCDA), using the AHP technique for the UGS planning process in Hue City. This city is well-known for its historical monuments and for being one of the few UNESCO-designated sites in Vietnam. The objectives of this study are to identify the distributions of the current UGSs and determine additional potential areas for UGSs in Hue City (to be developed by 2030).

2. Materials and Methods

2.1. Research Site

Hue is the capital of the Thua Thien Hue province in Central Vietnam. It is about 700 km south of Hanoi and about 1100 km north of Ho Chi Minh City. The location of Hue city is shown in Figure 1. The southern and southwestern areas of the city have low hills, while the rest of the area has a flat terrain. The climate is typical of the tropics, with heavy rainfall in October and November that can reach 800 mm/month. The highest temperature is in June, with an average of about 35 degrees Celsius; the lowest temperature is in January, with an average of 15 degrees Celsius [40].

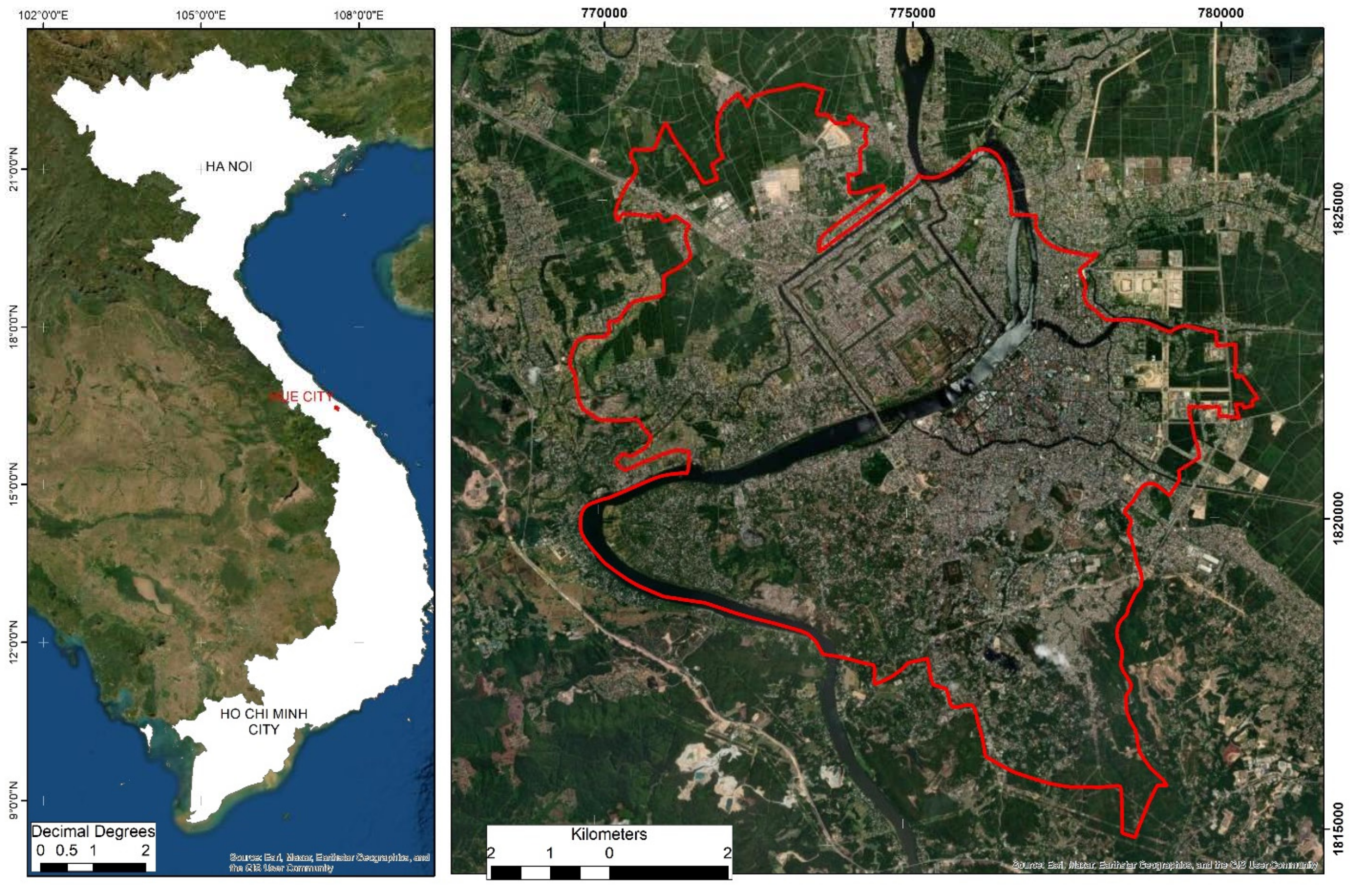

Figure 1. The location of Hue in Vietnam (*Sources: GADM database; https://gadm.org/data.html; 20 May 2021*).

This city is known as a green city that has been developed to accommodate the tourist industry. Hue was not only a historical political center, but it was also a cultural and religious center under the Nguyen Dynasty. This was the last royal dynasty in the history of Vietnam (from 1802 to 1945). A complex of imperial monuments was recognized by UNESCO as a world cultural heritage site in 1993. As a result, the city's economy is primarily built around tourism, with nearly 4.2 million visitors to Hue City in 2019. In 2020, Hue constituted a total of 7083 hectares with a population of 362,000 [40].

2.2. Methods

2.2.1. Focus Group Discussion

A focus group discussion, in this context, involves gathering people from similar backgrounds or experiences together to discuss a specific topic of interest. It is popularly used as a qualitative approach to gain an in-depth understanding of specific issues, especially regarding social aspects [41]. The size of the focus group discussion depends on many factors, including similar experiences within the given group, the professional achievement levels of individual research objectives, and the deductive abilities of moderators [42]. Most researchers suggest that the appropriate group size ranges from four to twelve participants [43]. In this research, we conducted a focus group discussion meeting with ten participants composed of citizens and staff members from local agencies responsible for the development of UGS planning. Six local residents were selected randomly based on their regular exposure to common UGS locations within Hue City. The other four participants were from local agencies, including the Department of Natural Resources and Environment, the Department of Urban Management, the Hue Monument Conservation Center, and the Hue Urban Environment and Construction Joint Stock Company.

2.2.2. Geographical Information System and Remote Sensing

GIS and remote sensing have been applied in many spatial planning projects, especially for UGS studies. The updated information on certain spatial areas (regarding the current statuses of UGSs) is crucial for land users and land use planning decision-makers [44]. Remote sensing is also very common in UGS mapping, in conjunction with various other methods, such as the object-oriented approach, support vector machines, deep neural networks, and maximum likelihood [45–47]. In this study, we used ArcGIS software to analyze and manage the spatial database, including the raster and vector data. The land use purposes were extracted from the Hue City land use map, which was created in 2020. The land surface cover was analyzed based on Landsat 8 imagery, which was taken on 29 March 2021; the cloud cover ratio of the research site was 0%. The resolutions of all raster data were 30 m.

2.2.3. The Analytic Hierarchy Process (AHP)

The AHP originates in findings by Thomas. L. Saaty, in relation to the multiple criteria decision analysis technique [48]. This has been the most popular method used in recent years pertaining to research relevant to qualitative and quantitative aspects [49]. This method primarily derives a priority scale through a pairwise comparison of attributes based on participant judgments [48]. There are five steps to the MCDA method using the AHP technique. These include the selection and set-up of the hierarchal structure, pairwise comparison for selected criteria, validation of the pairwise comparison via the consistency ratio, scoring for the characteristics of each criterion, and calculating the final score of each land map unit to be assigned to a suitable class.

- Step 1—selection of criteria and setting up a hierarchy structure.

Regarding the purpose of the evaluation process—the number of criteria related to the AHP method differs. In recent UGS studies in Vietnam, the most popular criteria are the industrial zones, air pollution, bodies of water, waste areas, noise pollution, and landscapes [50,51]. These are general criteria that are suitable for big cities, such as Ho Chi Minh City and Hanoi. For smaller urban areas, green space characteristics are more specific to their locations, involving their individual distances and infrastructure [3]. Therefore, in our research, we proposed six criteria for AHP analysis the distance from sources of pollution sources, the normalized difference vegetation index (NDVI), the distance from historical sites, the distance from existing residential areas, the distance from main roads, and the current land uses for the different areas. The characteristics of these criteria are described in Table 1.

Table 1. The criteria and their characteristics for AHP.

Criterion	Characteristic	Weight	Score			Sources
			Min	Mean	Max	
Distance from pollution sources	<300 m	0.19	1.00	2.19	3.00	Land use map in 2020
	300–500 m		4.00	5.34	7.00	
	500–1000 m		7.00	7.59	8.00	
	>1000 m		9.00	9.00	9.00	
Normalized Difference Vegetation Index	<0.1	0.13	1.00	1.81	2.00	Landsat 8 OLI
	[0.1–0.2)		5.00	5.63	7.00	
	[0.2–0.3)		7.00	7.57	9.00	
	≥0.3		8.00	8.89	9.00	
Distance to historical sites	<300 m	0.08	9.00	9.00	9.00	Land use map in 2020
	300–500 m		8.00	8.38	9.00	
	500–1000 m		6.00	6.76	7.00	
	>1000 m		5.00	5.86	7.00	
The distance to residential areas	200 m	0.36	8.00	8.69	9.00	Land use map in 2020
	200–500 m		7.00	8.08	9.00	
	500–1000 m		5.00	6.45	7.00	
	>1000 m		3.00	5.03	6.00	
The distance to main roads	<200 m	0.17	8.00	8.48	9.00	Land use map in 2020
	200–500 m		7.00	7.77	8.00	
	500–1000 m		5.00	6.06	7.00	
	>1000 m		3.00	3.84	6.00	
Current land use types	Agricultural land	0.07	7.00	7.97	9.00	Land use map in 2020
	Bare land		6.00	7.46	8.00	
	Construction land		1.00	1.00	1.00	
	Current UGS		8.00	8.69	9.00	
	Historical sites		1.00	1.91	3.00	
	Cemetery, industrial land		1.00	1.00	1.00	
	Residential areas		1.00	1.28	2.00	
	Road land		1.00	1.00	1.00	
	Waterbody		1.00	1.00	1.00	

Distance from pollution sources: This criterion investigates the negative impacts of pollution-causing locations, depending on the proximity of residents to them (in relation to corresponding UGS locations). They include landfill sites, industrial sites, slaughterhouses, and wholesale marketplaces dealing in industrial or agricultural products. Previous research in China suggested that the best distance between pollution sources and a given UGS is over 1000 m, and the minimum acceptable distance is 300 m [52].

Normalized difference vegetation index: This criterion compares the growth areas of vegetation. The NDVI values can be used to determine the different categories of urban vegetation, as was noted in previous research [53]. A series of NDVI values were suggested to classify the vegetation cover in urban areas. For an UGS, the NDVI value should be more than 0.1, indicating the shrubs and grasslands [52].

Distance from historical sites: Historical sites are prolific symbols in Hue City, which was the capital of the last feudal dynasty of Vietnam. Thus, in Hue City, UGSs serve locals as well as the thriving tourist industry. According to Shiva (2019), areas that are nearer to historical and cultural spaces are more suitable for healthy lifestyles compared to areas that are further away from these spaces. This is evident in areas that are 500 to 1000 m away from such places compared to areas that are 2000 m or more away [54].

The distance to existing residential areas: In Europe, the European Environment Agency (EEA), in defining the green space provision target, maintains that an individual should have access to a green space within 15 min (walking distance) of their residence, approximately 900–1000 m [55]. However, such stipulations may differ depending on the country. For example, in places such as Germany or Sheffield, England, most people have access to green spaces within approximately 500 m of their residences [56]. In this study, all of the participants agreed that the distances from their houses to UGS areas should be divided into four categories: less than 200 m, from 200 to 500 m, from 500 to 1000 m, and further.

The distance to main roads: The distance from UGSs to roads is very important regarding people's ability to easily access UGS areas. Due to the dense traffic system in Hue City, the discussion participants agreed to classify this criterion into four groups in relation to accessibility to residential areas.

Current land use type: The land use types were extracted from the land use map for 2020 and the annual report from the Natural Resources and Environment Department of Hue City. Land use purposes play an important role in the selection of locations for UGSs. The current land use type determines the feasibility of UGSs. Experience has shown that it is very difficult to include additional UGSs in existing areas under construction because of the disruptions to previously designated or contracted planning arrangements, economic considerations, as well as social disruptions.

- Step 2—pairwise comparison.

The purpose of the pairwise comparison is to clarify the levels between each criterion in the AHP model. This is based on a numerical scale that was proposed by Saaty, as shown in Table 2.

Table 2. Numeric scale for the pairwise comparison.

Numeric Scales	Response Alternatives of Participants
9	Criterion *i* is extremely more important than criterion *j*
7	Criterion *i* is strongly more important than criterion *j*
5	Criterion *i* is more important than criterion *j*
3	Criterion *i* is slightly more important than criterion *j*
1	Criteria *i* is equally important as criterion *j*
1/3	Criterion *i* is slightly less important than criterion *j*
1/5	Criterion *i* is less important than criterion *j*
1/7	Criterion *i* is strongly less important than criterion *j*
1/9	Criterion *i* is extremely less important than criterion *j*

The participant opinions changed from quantitative data to qualitative data. Since multiple participants were involved in this discussion, we used the geometric mean technique to synthesize the group opinions in a similar way to what has been outlined in previous research [57]. Subsequently, the expert opinions have been incorporated as the original matrix (A), as follows:

$$A = \begin{pmatrix} 1 & A_{12} & A_{1i} & A_{1j} & A_{1n} \\ A_{21} & 1 & A_{2i} & A_{2j} & A_{2n} \\ A_{i1} & A_{i2} & 1 & A_{ij} & A_{in} \\ A_{j1} & A_{j2} & A_{ji} & 1 & A_{jn} \\ A_{n1} & A_{n2} & A_{ni} & A_{nj} & 1 \end{pmatrix} \tag{1}$$

$$A_{ij} = \left(\prod_{k=1}^{p} a_{ijk}\right)^{\frac{1}{p}} \tag{2}$$

where:

A_{ij} is the important level of criteria i compared to criteria j;
a_{ijk} is the important level of criteria i compared to criteria j by participant kth;
k is the number of participants in the discussion.

The matrix B was created from matrix A based on the normalized technique as follows:

$$B = \begin{pmatrix} \overline{A}_{11} & \overline{A}_{12} & \overline{A}_{1i} & \overline{A}_{1j} & \overline{A}_{1n} \\ \overline{A}_{21} & \overline{A}_{22} & \overline{A}_{2i} & \overline{A}_{2j} & \overline{A}_{2n} \\ \overline{A}_{i1} & \overline{A}_{i2} & \overline{A}_{ii} & \overline{A}_{ij} & \overline{A}_{in} \\ \overline{A}_{j1} & \overline{A}_{j2} & \overline{A}_{ji} & \overline{A}_{jj} & \overline{A}_{jn} \\ \overline{A}_{n1} & \overline{A}_{n2} & \overline{A}_{ni} & \overline{A}_{nj} & \overline{A}_{nn} \end{pmatrix} \tag{3}$$

$$\overline{A}_{ij} = \frac{A_{ij}}{\sum_{i=1}^{n} A_{ij}} \tag{4}$$

where:

$\overline{A}_{ij}$ is the normalized value of C_{ij};
$\sum_{i=1}^{n} A_{ij}$ is the sum of A_{ij} by column j from matrix A;
n is the number of compared criteria.

From the matrix B, the criteria weights can be derived as follows:

$$w_i = \frac{\sum_{j=1}^{n} \overline{A}_{ij}}{n} \tag{5}$$

$$W = \begin{pmatrix} w_1 \\ w_2 \\ w_i \\ w_j \\ w_n \end{pmatrix} \tag{6}$$

where:

w_i is the weight of criteria i
$\sum_{j=1}^{n} \overline{A}_{ij}$ the is sum of A_{ij} by row j from matrix B

- Step 3—validation of the prioritized level.

The matrix B can be used for a comparison between the criteria. However, the inconsistent level of this comparison needs to be checked in this matrix. The inconsistent level involves the results of the different opinions of participants in the discussion; it could also be among the deferent criteria of one participant. Saaty (1987) [48] suggested an index call consistency ratio (CR), which serves to validate the consistency of the compared matrix as follows:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{7}$$

where:

CR is the consistency ratio;
RI is the random index already provided by Saaty (1987) [48] as shown in Table 3;
CI is the consistency index (CI) obtained by calculating:

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \tag{8}$$

$$\lambda_{max} = \frac{\sum \frac{\sum_{j=1}^{n} w_i * A_{ij}}{w_i}}{n} \tag{9}$$

Table 3. Random Index based on the number of criteria.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Many researchers agree that the CR ≤ 0.1 can be accepted for the AHP method [48].

- Step 4—scoring for the characteristics of each criterion.

The assignment of weights is not yet sufficient to determine the suitability of certain area characteristics for a UGS (as the suitability of each attribute within each criterion is different). Therefore, researchers need to score the specific attributes of each criterion to clarify the suitability of the goal in the evaluation process as shown in Table 4. These values were collected from the participants in the discussion and used as the geometric means to calculate the final score for each characteristic of the selected criterion.

Table 4. Scale for scoring according to the PRA method.

Score (X_i)	Definition
7–9	Criterion is suitable for UGS without any concerns.
5–7	Criterion is suitable for UGS with few concerns.
3–5	Criterion may be suitable for UGS with many concerns.
1–3	Criterion is unsuitable for UGS.

- Step 5—calculate the final score of each land map unit and the suitability classifications.

The final score of the specific land map unit will be calculated using the following formula.

$$S_a = \sum_{i=1}^{n} W_i * X_{ia} \tag{10}$$

where S_a is the score of the land map unit a; W_i is the weight of criterion i; X_{ia} is the score of the attributes of criteria i for the land map unit a, and n is the number of criteria.

For land map units that have scores of more than three, and if the scores of all criteria are greater than three, these areas will be considered suitable to be used in land evaluation for UGSs. Land units that do not meet the above conditions will be considered completely unsuitable for UGSs.

3. Results

3.1. The Selection of Criteria

The distance from pollution sources (Figure 2): The pollution sources are mainly located in the southern and northern areas of the city. These areas are mainly the areas dedicated to cemeteries, of which there are many southern parts in Hue and the industrial production areas in the northern part of the city. A total of 3196 hectares are within 300 m of pollution sources; from 300 to 500 m, there is 1128 ha; from 500 to 1000 m, there is 1579 ha; as for the remaining areas far from the pollutants—more than 1000 m.

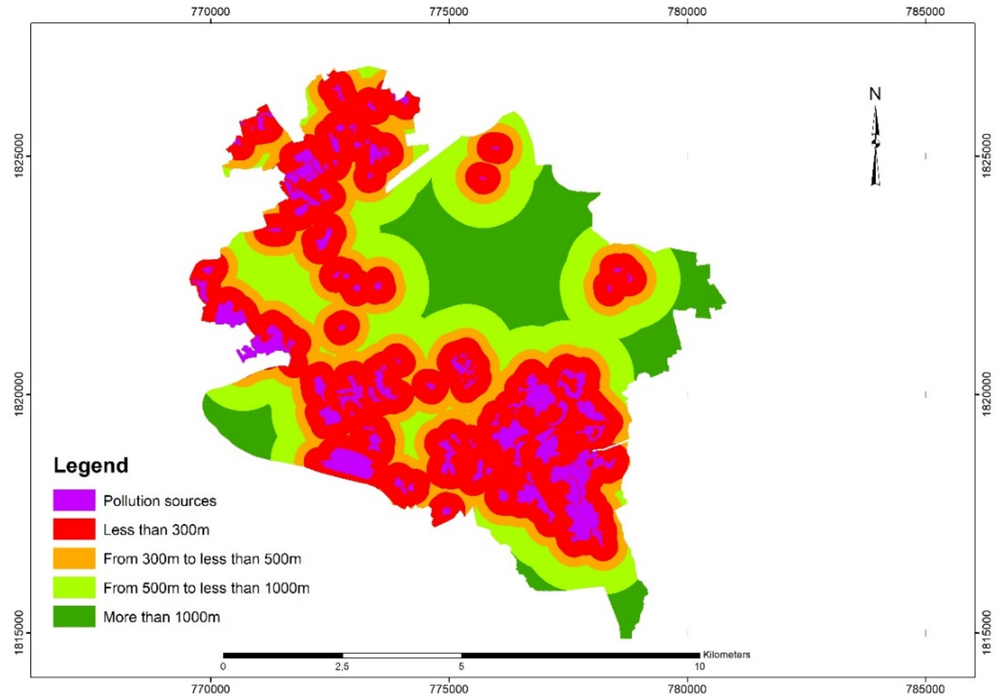

Figure 2. Map of the distance from pollution sources (*sources: authors; Land Use Map in 2020 of Hue City*).

Normalized Difference Vegetation Index (Figure 3): This criterion of the research site ranges from 0.0 to 0.39. There are 480 hectares with an NDVI value of less than 0.1, with the main land use types being water and bare land. The area where NDVI ranges from 0.1 to 0.2 is about 3000 ha concentrated in the center of the city, with the main land use types being residential and construction land. Suburban areas have the highest NDVI because these are the areas with forest land, agricultural land, and household gardens.

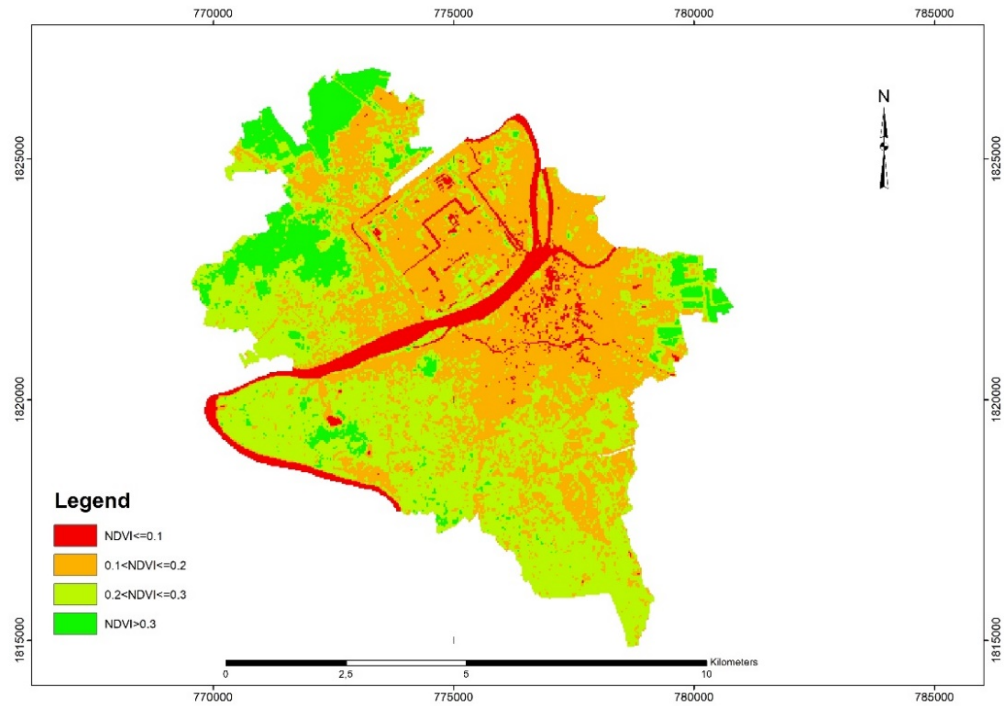

Figure 3. Map of normalized difference vegetation index (*sources: authors; Landsat 8 Image on 29 March 2021*).

Distance from historical sites (Figure 4): There are many relics and historical sites in Hue City. We used statistical data from the Tourism Department of Hue City and subsequently listed the places that were most visited by tourists in 2019. There were ten places listed—the Hue Imperial Citadel, Tu Duc mausoleum, Thien Mu pagoda, Tu Hieu pagoda, Tu Dam pagoda, Tay Thien pagoda, An Dinh palace, Nam Giao palace, the Church of the Savior, and Phu Cam church. There are 618 hectares within a radius of 300 m from the historical sites; 516 hectares in the range of 300–500 m; 1418 hectares in the range of 500 to 1000 m; and the remaining areas—far more than 1000 m.

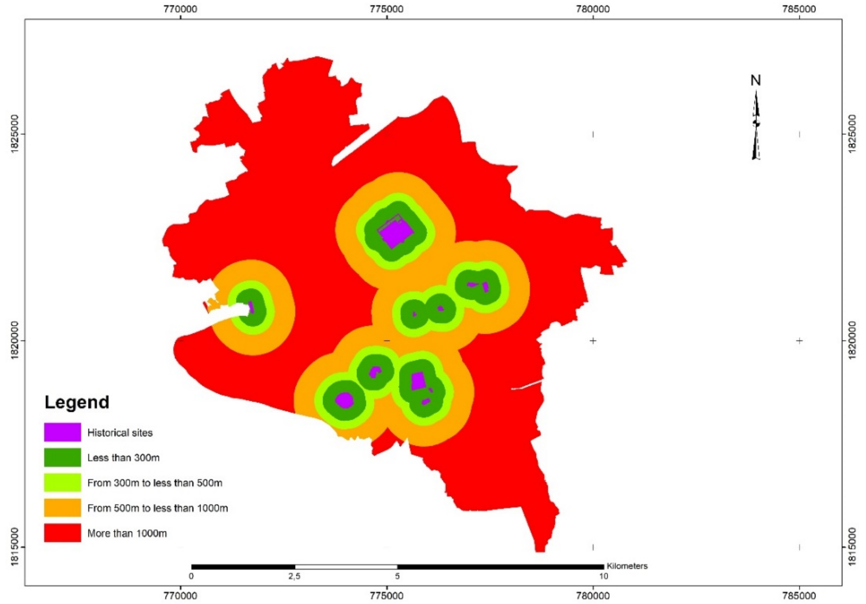

Figure 4. Map of the distance from the historical sites (*sources: authors; Land Use Map in 2020 of Hue City*).

The distance from existing residential areas (Figure 5): The residential areas in Hue City are widely distributed in the territory, among which, the area of the city center and the area north of the Perfume River (Huong River) have the highest population densities. As a result, more than 80% of the city's area is within 200 m of existing residential areas.

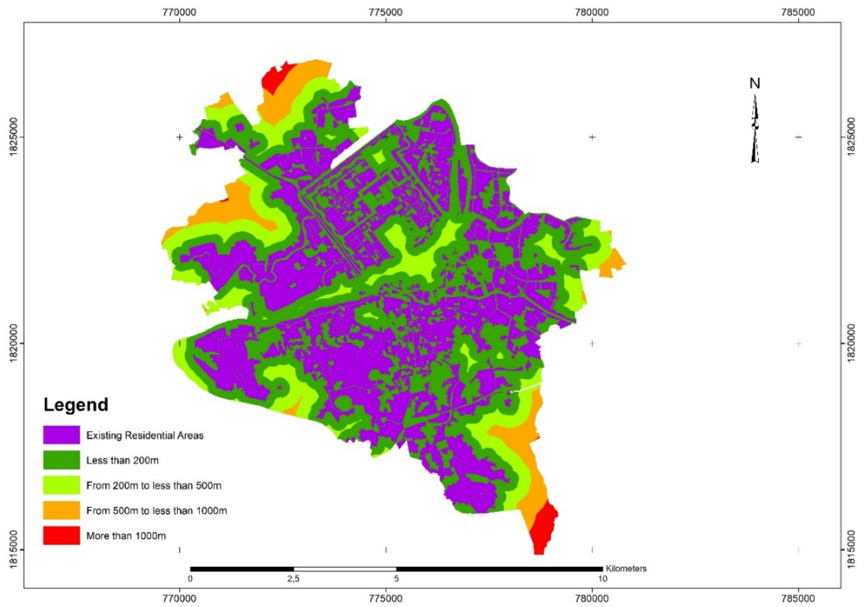

Figure 5. Map of the distance from existing residential areas (*sources: authors; Land Use Map in 2020 of Hue City*).

The distance from main roads (Figure 6): The traffic system in Hue City was developed haphazardly, with the highest density in the downtown area. The areas in the southwestern and northwestern regions of the city are mainly agricultural land, and the road system is less developed than in other areas. Therefore, there is about 500 ha far from the main roads, with a distance that is more than 500 m.

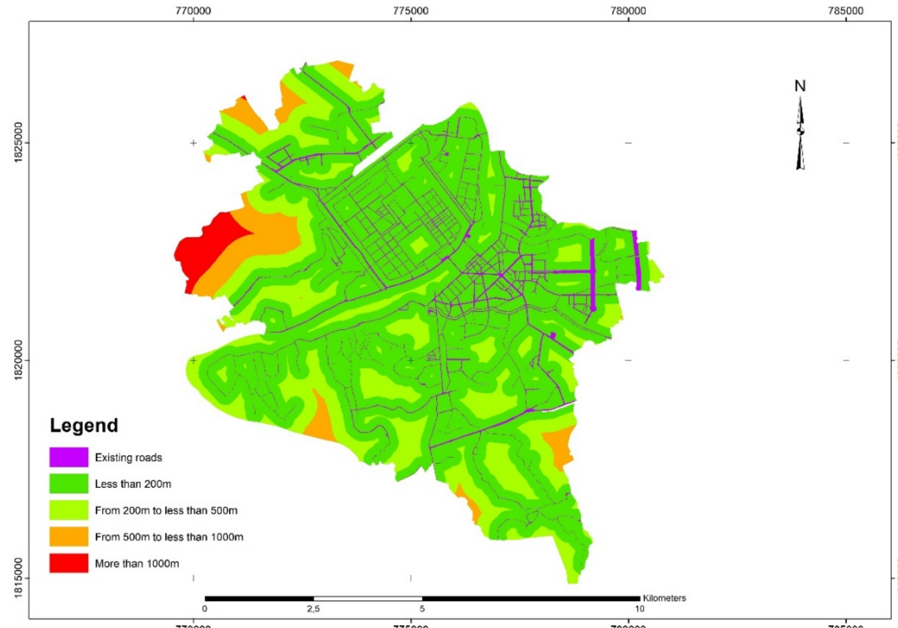

Figure 6. Map of the distance from main roads (*sources: authors; Land Use Map in 2020 of Hue City*).

Current land use types (Figure 7): There are nine land use types in Hue City, as reported by the Natural Resources and Environment Department in 2020. The area for residential land is the largest, with 2830 ha, followed by agricultural land and construction land at 1810 hectares and 617 hectares, respectively. There are 13 hectares of unused land distributed sporadically throughout the city. The remaining land areas are as follows: water bodies (676 hectares), road land (366 hectares), land with historical sites (80 hectares), industrial zone and cemetery land (576 hectares), and the area for the UGS (88.56 hectares).

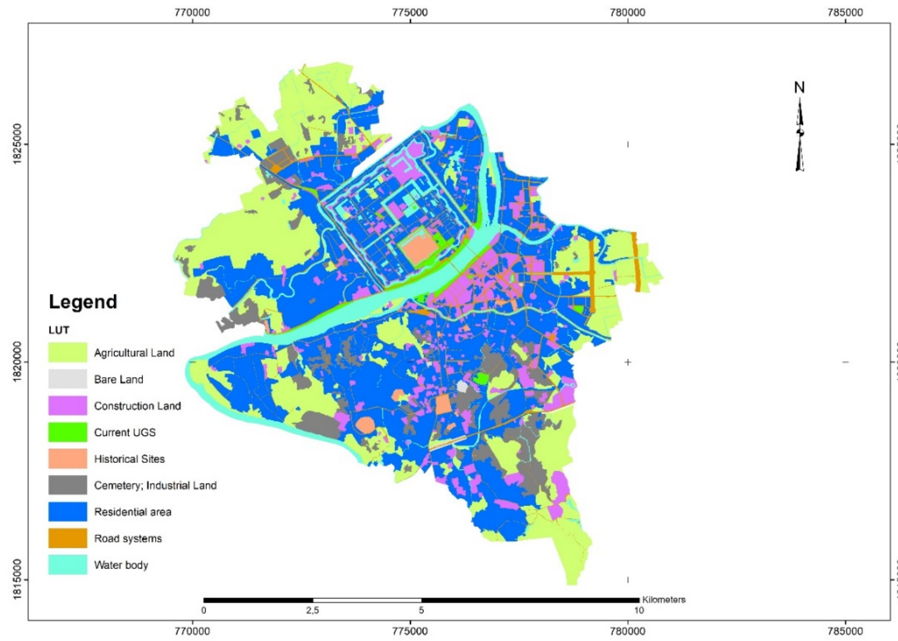

Figure 7. Map of the current land use types (*source: Land Use Map in 2020 of Hue City*).

3.2. Criteria Weights and Scores

The weights of the criteria and scores of their attributes are shown in Table 1. The criteria weighting indicates that the various criteria have different levels of importance in regard to potential selections for UGSs. The distances from residential areas are crucial; followed by the distances from historical sites and the distances from roads. We also found that there were differences in opinion among our discussion participants. Those who work in the land management sector and urban development considered the type of land use to be the most important, while other participants considered the convenience of accessing UGSs to be the most important criterion.

The scoring of the criteria attributes involved an assessment of each location for UGS suitability. For each criterion, there were specific attributes that could be evaluated and scored based on the knowledge that they elicited individually. For distances from historical sites, distances from existing residential areas, and distances from the main road ranges within 500 m—all participants agreed that these are very suitable for UGS designation. In contrast, the minimum distance from pollution sources should be 500 m for UGS; however, in this, there are still health concerns in regard to residents. According to NDVI values, the most suitable areas are those where there is dense vegetation. In addition, an UGS is deemed inappropriate in an area with a NDVI of less than 0.1. Concerning land use types, the most suitable for an UGS include areas that have been previously unused, or that have been used for agriculture or current UGSs. Other land-use types listed previously are not suitable to change to UGS land.

3.3. Suitability Map for Urban Green Spaces in Hue City

The suitability map for urban green spaces is shown in Figure 8. In this map, three categories were created to indicate the levels of suitability for UGS. The categories include: non-suitability (N class) with 6164 hectares; high suitability (S1 class) with 684 hectares; and medium suitability (S2 class) accounting for 210 hectares. The S1 class includes the current UGSs and three bigger sections at the eastern, western, and southern parts of the city where agriculture is the dominant land use type. The S2 class is distributed mainly in the southern and northern areas of the city, where the majority of forest land and agricultural land are located far from existing residential areas. The remaining areas are not suitable for UGSs because those areas are residential areas and construction land.

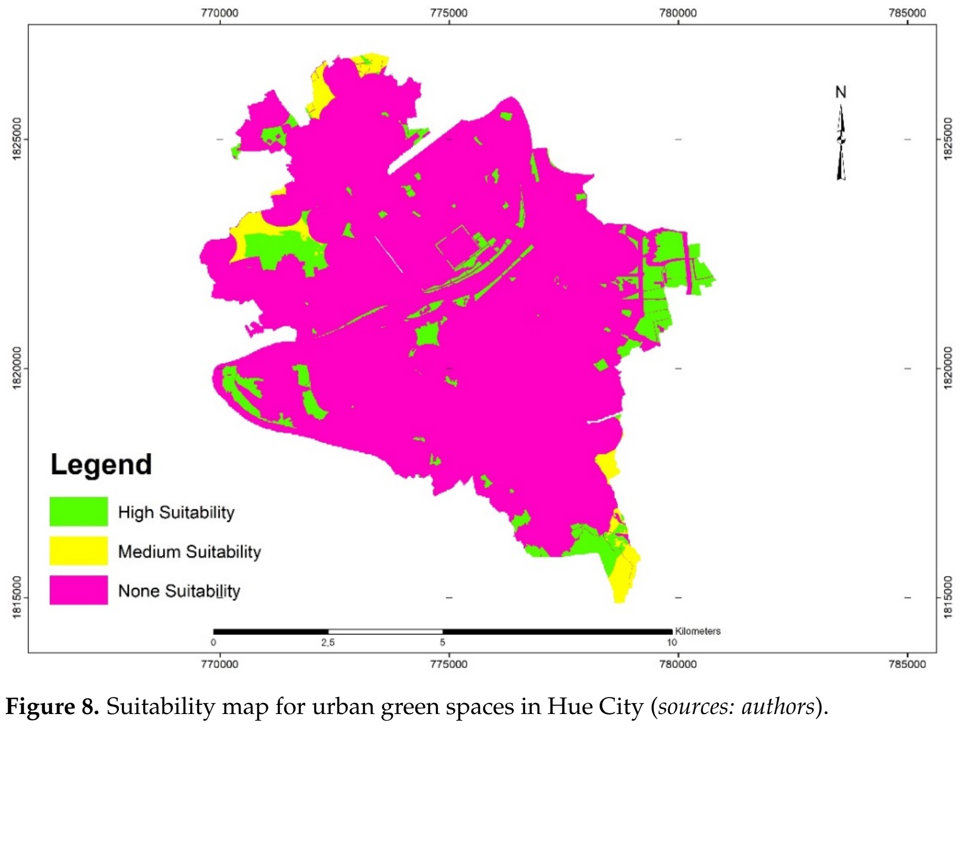

Figure 8. Suitability map for urban green spaces in Hue City (*sources: authors*).

In comparison to the current UGSs, there are 81.05/88.57 hectares, approximately 92% of current UGSs belonging to the S1 class. Only one current UGS belongs to the N class. The reason is that the UGS is a complex of green spaces and monuments. There are many cemetery lands around this space, leading to a low score of the criterion 'the distance from polluting areas'.

According to the land use planning scheme of Hue City in 2030—nine big residential areas will expand (a total of 350 hectares). These areas will extend from agricultural land so it will be more convenient to arrange parks without having to acquire land, especially residential land. These are areas with traffic infrastructure, so it will be very convenient to connect them with other areas. These areas need to be prioritized to arrange a UGS network (to meet the needs of local residents). Therefore, we suggest the following criteria when selecting UGS areas for Hue in the future:

(i) The UGS must belong to a highly suitable class, as shown in the suitability map.
(ii) The UGS should be close to existing as well as developing residential areas.
(iii) The UGS should have a minimum size of 1 hectare.
(iv) The ratio of UGS per capita must meet the regulations set forward by the government, with a minimum of 6 m^2 per capita, where the estimated population in 2030 will be 400,000 people.

With these criteria, thirty-five locations were selected for new UGS planning in 2030 for Hue City. The new UGSs will occupy 167 hectares and will be evenly distributed throughout the entire area of Hue City. This is detailed in Figure 9.

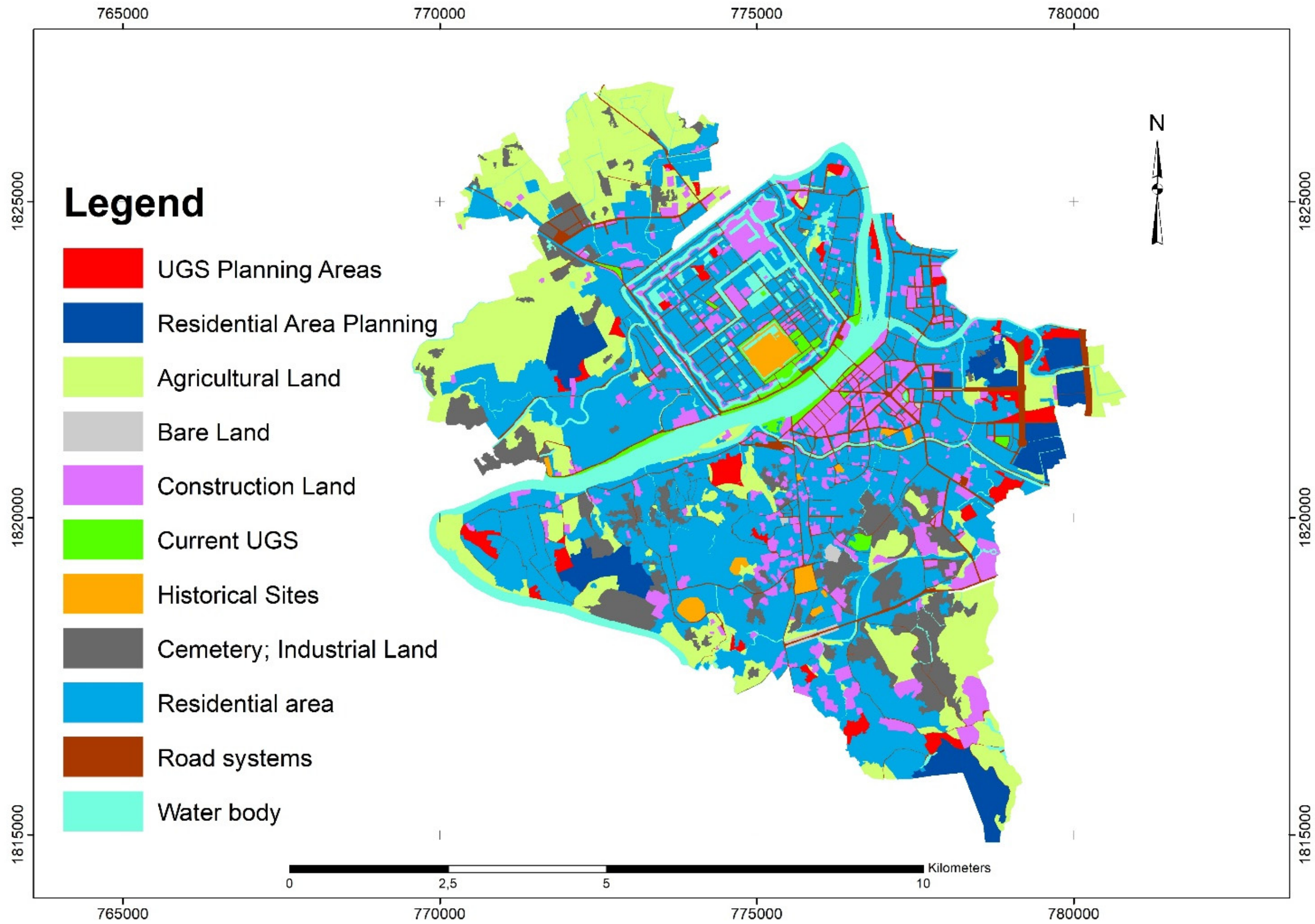

Figure 9. Map of the suggested UGSs for land use planning in 2030 in Hue City (*sources: authors; Land Use Planning Project of Hue City in 2030*).

4. Discussion

Our findings indicated that there were twenty-one UGS in Hue with a total area of 88.67 ha. Most of these places are located along the Huong River and around the Hue Imperial Citadel. When compared with other cities that have the same natural conditions, and compared to an ancient capital in Asia, such as Kyoto (Japan), we found similarities in the locations of the urban green spaces. We determined that there are two main reasons for the current locations of UGSs in Hue City—the Hue Imperial Citadel area is managed under the heritage conservation laws of Vietnam and there is an international agreement between Vietnam and UNESCO regarding the protection and enhancement of cultural heritage sites [58,59]. The areas around cultural heritage sites are often protected areas (in class I and class II). This is a case where it is forbidden to change the current status of an existing landscape or to build new structures within the protected areas. In addition, these areas are often planted with trees, shrubs, and grass (thus forming urban green spaces). Furthermore, these areas cater to tourists, so it is in the interest of policymakers to ensure that they are kept clean and aesthetically pleasing. They are designed and planted with various types of pleasing vegetation and are cared for by specialized agencies, such as the Green Tree Company and the Hue Monument Conservation Center. The development of UGSs in conjunction with tourism and public attractions has been well documented in many sites around the world [60]. The second observation is that the soil quality of riverbanks is better than in other areas of the city because these areas are regularly accreted with alluvium [61]. Better soil quality leads to better vegetation growth, creating green patches in the city.

In Vietnam, UGS development still faces some difficulties, especially in achieving a balance between the perceived benefits of UGS areas and the economic value of land for other urban purposes. Areas that are large enough, topographically flat, and have favorable locations for UGS purposes often also have high economic values in terms of other economic uses [62]. The average area of an individual UGS in Hue is 4.2 hectares/UGS. Six UGSs have areas of less than one hectare, and seven UGSs have areas from one to five hectares. The remaining UGSs are larger than five hectares. In comparison to other cities in Vietnam, such as Ho Chi Minh city, only eight out of a total of 108 UGSs have areas that are over five hectares [63]. This was also the same in Hanoi, leading to the situation that the most densely-populated residential areas only have access to relatively small gardens and parks, which results in overcrowding [64]. However, it can be seen that the majority of green spaces in Hue are classified as small green spaces according to the classification by Gozalo et al. [65], who stated that UGSs with areas smaller than ten hectares were classified as small UGSs. The size of an UGS also has a significant positive correlation to activities, such as walking, relaxing, and exercising, [66,67]. At present, the green space density of Hue City does not meet the current standards of Vietnam. According to Vietnam's regulations; for urban centers of grade I, the ratio of urban trees for each resident is 5–7 m^2/capita; however, in Hue City; this rate is only about 2.5 m^2/capita. This is an issue that needs special attention in Vietnam. Some recent studies have shown that this rate in Ho Chi Minh city is 0.22 m^2/capita [63] and Hanoi is 1.48 m^2/capita [62]. While the per density green space per capita in Hue is higher than several other large cities in Vietnam, it is lower than large cities in other developing countries, such as Singapore (10 m^2 [68]) and Beijing (at 15.7 m^2 [69]). According to Hue's Department of Natural Resources and Environment, there were more than 38,000 planted trees along the streets and roads in Hue in 2020. However, these green spaces cannot meet the needs of local residents because the sidewalk system is not synchronized and is affected by traffic issues. The agricultural lands in remote areas of Hue City also contribute to green spaces. However, these green spaces do not meet the standards of becoming urban green spaces because residents do not have ready access to make use of these areas. Therefore, Hue City needs strategies and policies to develop urban green spaces.

According to recent research [70], the surface temperatures of areas in Hue City where the green spaces appear are lower than in other regions by an average of 2.8 degrees. This finding further corroborates the positive effects of UGSs upon urban micro-climates via the mitigation of urban heat islands during hot seasons. In addition, during rainy seasons, UGSs help to protect urban areas from the destructive effects of flooding by holding the topsoil in place and rerouting accumulated water run-off.

5. Conclusions

The current UGSs in Hue City are unevenly distributed throughout the city, and many residential areas in core urban areas in the south of the city do not have access to UGS services. Although Hue has many green spaces, it is mainly due to the agricultural land and the tree-lined street systems. The area of green spaces per capita in Hue is still low and does not meet the regulations for grade I urban areas. In the future, the urbanization of Hue will rapidly increase due to its projected development (i.e., its classification as a municipal city). Given these considerations, the augmentation of UGSs within the city will face difficulties due to the lack of available land set aside for this purpose, and the lack of municipal financial incentives.

By 2030, Hue City would need to have retained its existing green spaces as well as added many public facilities to serve the increased population of residents. In conjunction with the expansion of urban residential areas, it will be necessary to arrange (at least) an additional 167 hectares of UGS land. In areas where green spaces are being planned for the future, it will be imperative to invest in infrastructures, such as internal paths for pedestrians and bicycles, outdoor exercise equipment, and green spaces for events and family gatherings. In addition, it is necessary to select horticulture that is suitable for local climatic conditions to ensure their survival during the annual rainy seasons.

The existing condition that 92% of the current UGS land areas coincide with the high suitability class means that the AHP method, when combined with the knowledge and opinions of local residents, can be applied to evaluate the future selection of UGS areas that are necessary to meet the needs of local residents. Although there is some controversy about the flexibility of the AHP method, this method does take into account all of the opinions of the participants, so that future UGS planning benefits from the consensus of the most important stakeholders.

This study was conducted to assess the most basic criteria for UGS planning, allowing for the results from this study to be used for the whole city, or on a smaller scale, i.e., in relation to specific areas of the city. For each specific area, it is necessary to take into account many factors concerning the local population (e.g., the average age, general standards of living, and income) to have detailed and practical UGS planning for each residential area. The methodology of the criteria selection for this study is based on the individual requirements of specific local stakeholders, making this research approach adaptable in choosing suitable criteria that will coincide with the unique natural conditions and eco-social requirements of the particular urban area being studied.

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